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The *Challenger* Expedition (1872–1876), Henry Bowman Brady (1835–1891) and the *Challenger* Foraminifera

ROBERT WYNN JONES

BP Research Centre, Chertsey Road, Sunbury-on-Thames, Middlesex, TW16 7LN

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INTRODUCTION

It is now over a hundred years since the cruise of H.M.S. *Challenger* (1872–1876) and the subsequent publication of the report on the *Challenger* foraminifera by Henry Bowman Brady[1] (1884); indeed, 1991 marks the centenary of Brady's death. So why the interest? The answer is two-fold but simple.

Firstly, because the *Challenger* expedition fundamentally and significantly advanced numerous fields in the earth, life and ocean sciences, and indeed has been described as representing 'the greatest advance in the knowledge of our planet since the celebrated geographical discoveries of the fifteenth and sixteenth centuries' (Linklater, 1972). It also heralded the dawn of a new, modern, multi-disciplinary era of oceanography, such that its significance may be justly compared with that of the voyage of the *Beagle* (made famous by Charles Darwin) in other areas of scientific interest and endeavour.

Secondly, because Brady's work on the *Challenger* foraminifera detailed for the first time the dominant microfaunal element in the largest biotope on the face of the earth—the abyssal plains of the deep sea—until shortly beforehand thought to be incapable of sustaining life. The *Challenger Report* (Brady, 1884) features 915 (15% of the total number of extant) species belonging to 368 (44% of the total number of extant) genera, including the type-species of 284 genera (34%). The comprehensiveness and attention to detail exhibited in this work is such that it remains the most famous of the classic monographs of foraminiferal studies and the most often cited. Also, of all the collections in the British Museum (Natural History), none is more important or more frequently consulted than the *Challenger* collection.

This paper consists chiefly of historical notes on the *Challenger* expedition, biographical notes on H. B. Brady and curatorial notes on the *Challenger* foraminifera. The concluding part outlines plans for a taxonomic revision of the *Challenger* foraminifera.

THE *CHALLENGER* EXPEDITION (1872–1876)

Prelude to the Expedition

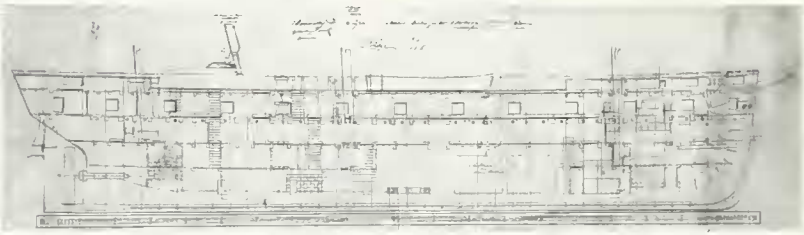
The reasoning behind the commissioning of the *Challenger* expedition is best understood in its historical context. Britain in the latter half of the last century was at her mightiest as an imperial power. She was above all a maritime power, proud of her naval achievements at war and in peace-time.

When the news of impending American and German voyages of scientific exploration broke in London in 1871, William Benjamin Carpenter (1813–1885) urged prompt action to maintain Britain's leading position in marine science. In an address to the Royal Institution and later in a letter to G. G. Stokes (Secretary of the Royal Society, of which Carpenter was President), Carpenter suggested the draughting and submission to parliament of a joint plan for a circumnavigation of the globe which would take the concepts and techniques developed and pioneered on the North-East Atlantic voyages of the *Lightning* (1868) and *Porcupine* (1869, 1870) and put them to work on the oceans of the world. In further correspondence with George Goschen (First Lord of the Admiralty), Carpenter received assurances that the government would give favourable consideration to such a proposal.

Carpenter was a remarkable man who held a number of honorary positions and titles and was at various times Lecturer on Medical Jurisprudence at the Bristol Medical School, Lecturer on Physiology at the London Hospital, Fullerian Professor of Physiology at the Royal Institution and Professor of Forensic Medicine at University College, London and Registrar of the University of London. In the words of the *Dictionary of National Biography* (Lee, 1898), he was '... a man of no ordinary mental grasp and range of study ...' and '... one of the last examples of an almost universal naturalist ...'. He published variously on physiology, behavioural psychology, evolutionary theory (a deeply religious man who played the organ at the Unitarian Church in Hampstead, he was a rather reluctant ally of Darwin) and microscopy, always in a lucid and often ratiocinative style. He was a particular authority on oceanography, marine biology and foraminiferology (see, for instance, Carpenter, 1862, 1883; Murray, 1971, 1981, 1989; Murray & Taplin, 1984a–b).

Once Carpenter's circumnavigation plan had been tacitly approved by the Admiralty, and the approval communicated to the Royal Society, a committee was set up under the auspices of that august body which comprised Carpenter himself, J. D. Hooker,

Plate 1 **Top left:** Carpenter. **Top right:** Hooker. **Bottom left:** Huxley. **Bottom right:** Jeffreys. From the Brady Family Photograph Album. Reproduced by kind permission of Newcastle-upon-Tyne City Libraries & Arts.



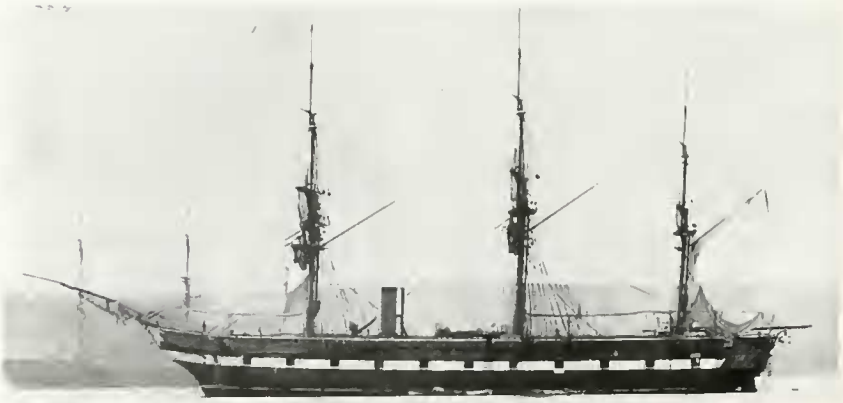


Plate 2 **Top:** H.M.S. *Challenger* in starboard view with funnel lowered. **Middle:** Plans for her refit. **Bottom:** Port view with funnel raised, Sydney approaches, June 1874. Reproduced by kind permission of the trustees of the National Maritime Museum, Greenwich.

T. H. Huxley, J. G. Jeffreys (see Plate 1), Captain Richards, Professor Charles Wyville Thomson and Sir William Thomson (later Lord Kelvin). On the recommendation of these eminent personages, the Council of the Royal Society made a formal request to the government to send out an expedition to undertake a scientific study of the oceans. The request was granted in April, 1872, and preparations for departure began immediately. The organisation of the voyage (Burstyn, 1968, 1972) proceeded remarkably swiftly and efficiently, due doubtless in part to previous experience in similar ventures but probably also in no small measure to political factors (it is noteworthy that Carpenter had social contacts with the then Prime Minister Gladstone).

A suitable vessel, H.M.S. *Challenger* (Rice, 1986; Plate 2) was chosen in the summer of 1872, and a schedule for her voyage drawn up for which the Navy Hydrographer G. H. Richards was largely responsible. *Challenger* was a 226′, 1462-ton (builder's measurement) or 2306-ton (displacement) 'Pearl' class steam-assisted screw corvette. Her engines were nominally of 400 h.p. but capable of 1234 h.p., and she also carried 16000 square feet of sail. She had been built at Woolwich in 1858 and had seen naval service off the Americas and later in Australasia before returning to England in 1871. Preparatory to what was to become her most famous voyage, she was fitted out at Sheerness, where all but two of her twenty-two cannon were removed to make way for a dredging platform over the upper deck forward of the main mast, extra laboratories, work-rooms and storage space.

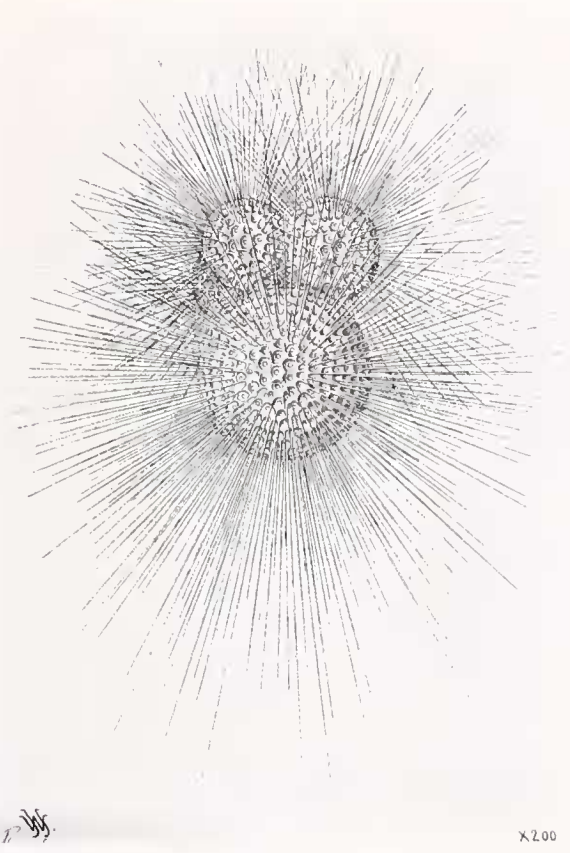
The Aberdonian Captain (later Rear-Admiral Sir) George Strong Nares (1829–1915) was chosen by the Admiralty to take the helm. Under him were some score of officers and crew (see Plate 3), including Paymaster R. R. A. Richards, Lieutenant P. Aldrich, Lieutenant A. Balfour, Sub.-Lieutenant Campbell and Navigating Sub.-Lieutenant Swire, all of whom kept journals (Swire's being memorable for some less than reverential references to Wyville Thomson's appearance and manner!) Nares left *Challenger* in 1874 to lead the *Alert* and *Discovery* Arctic expedition, and was replaced by Captain Frank Tourle Thomson. Aldrich left with him and was replaced by a Lieutenant A. Carpenter.

Wyville Thomson (see Plate 3) was appointed by the Royal Society as head of the civilian scientific team, Carpenter at 59 having decided he was too old to put to sea again. He was to be assisted on board by secretary and ship's artist John James Wild, chemist John Young Buchanan (see Plate 3) and three naturalists, Henry Nottidge Moseley, Rudolph von Willemöes-Suhm (whose promising career was cut short when he died on board *Challenger*) and John Murray.

Wyville Thomson was born in 1830 at Linlithgow in Scotland and received his early education at Merchiston Castle School. He matriculated at the age of sixteen as a student of Medicine at Edinburgh University, where he seems largely to have pleased himself in the choice of lectures he attended, taking in such subjects as zoology, botany and geology; he was also active in his role as Secretary of the Royal Physical Society. He gave up his medical studies in 1850 on the grounds of ill health and embarked instead on a career in natural science, succeeding to the posts of Lecturer in Botany at King's College, Aberdeen in 1850, Professor of Botany at Marischal College, Aberdeen in 1851, Professor of Natural History at Queen's College, Cork in 1853, Professor of Mineralogy and Geology at Queen's College, Belfast in 1854, Professor of Zoology and Botany at Belfast in 1860 and Allman Professor of Natural History at Edinburgh University in 1870. He was reputedly a delightful and instructive lecturer on a variety of scientific subjects, speaking without notes but with constant reference to the profusive array of specimens on his table.

Wyville Thomson was, with Carpenter, instrumental in setting up the *Lightning* and *Porcupine* expeditions, the results of which were published in his book *The Depths of the Sea* (Wyville Thomson, 1873). He was widely recognised on account of this work as an active instigator and leading spirit of new and successful investigations. It was natural

Plate 3 **Top left:** The crew of H.M.S. *Challenger*. *Standing (left to right)*: Balfour, Buchanan, Willemoes-Suhm, Aldrich, Ass. Engineer W. A. Howlett, Wild, Swire, Ass. Paymaster J. Hynes, Moseley, Sub.-Lieut. A Channer, Richards, Sub.-Lieut. H. E. Harston, Murray, Lieut. A. C. Bromley. *Seated (left to right)*: Cdr. J. F. L. P. Maclear, Surgeon G. Maclean, Nav. Sub.-Lieut. A. Havergal, Wyville Thomson, Engineer W. J. J. Spry, Nares, Staff Surgeon A. Crosby, Lieut. G. R. Bethel, unknown. **Bottom left:** Pen and wash sketch by Elizabeth Gulland showing Wyville Thomson (left) and Buchanan (right) at work on board *Challenger*. **Right:** Original drawing made by Wild on board *Challenger* of the planktonic foraminifer *Globigerina bulloides* d'Orbigny, subsequently used in the *Challenger Report* (Brady, 1884, Pl. 77). Signed bottom left. Reproduced by kind permission of Edinburgh University Library.



therefore that he should be appointed as chief naturalist on the *Challenger* expedition. It is unfortunate that his health broke down in the wake of the expedition and that he did not have the freedom to finish his original research on the *Challenger* crinoids and sponges, having to concentrate instead on his administrative responsibilities. Nonetheless he received international recognition for his career on the *Challenger*, which he wrote up in the form of the scholarly and erudite book *The Voyage of the Challenger* . . . (Wyville Thomson, 1877). For instance, he received a Royal Society Gold Medal in 1876 (having already acceded to the fellowship of that institution in 1869) and was made a Knight of the British Empire in 1876 and a Knight of the Polar Star (an honorary title bestowed at the University of Uppsala on the occasion of its quatercentenary celebrations) in 1877. He died in 1882, wherepon a memorial window was installed in the Linlithgow Cathedral and a bust in Edinburgh University. Further details of his life are given by Herdman (1923).

Moseley was a no less able or enthusiastic fellow, of whom it was once said that 'you had only to put him down on a hillside with a piece of string and an old nail, and in an hour or two he would have discovered some natural object of surpassing interest' (Herdman, 1923). He wrote up his experiences on board *Challenger* in the lively and

enjoyable book *Notes by a Naturalist . . .* (Moseley, 1879), the enduring popularity of which is evident from the fact that it was reprinted as recently as 1944 in a series entitled *Live Books Resurrected*! He went on from his *Challenger* exploits to become a Fellow of the Royal Society and Linacre Professor of Human and Comparative Anatomy at Oxford.

Murray (see, for instance, Herdman, 1923 & Boog Watson, 1967) was Canadian-born but of Scots ancestry. He registered as a medical student at Edinburgh University, where one of his fellow students, Robert Louis Stevenson, came to criticise him for failing to pursue his studies in 'orderly, purposive and profitable fashion'. Rather like Wyville Thomson before him, he attended lectures not strictly connected with his course-work, for instance on chemistry, natural history, literature, law and theology. He spent his summer vacations indulging his interests in marine biology and oceanography in dredging trips off the Scottish coasts (on one such occasion meeting Sir William Thomson on Skye) and had enterprisingly enrolled as a surgeon aboard the whaler *Jan Mayen* in 1868, spending 7 months in the Arctic. Enough was known of the rare talent of this remarkable man even by 1872, when he was only 31, that he was appointed to the prestigious post of *Challenger* naturalist (albeit as a replacement for William Stirling, who had resigned his appointment) on the recommendation of the eminent Edinburgh University physicist Professor Peter Guthrie Tait. He is acknowledged as the 'father of modern oceanography' on account of his many achievements in the wake of the *Challenger* cruise. He went on to be made a Fellow of the Royal Society in 1896 and was knighted in 1898.

By December, 1872, the scientists and crew were assembled and all the necessary equipment was on board. Most of the equipment had been tried and tested on earlier voyages. Nets, trawls and dredges were to be put out on hempen lines. Temperature measurements were to be taken with Miller-Casella thermometers (appropriately compensated for pressure), though some Siemen's and Johnson's instruments were also taken (as was Siemen's photometric apparatus). Intermediate depth water samples were to be collected by a stopcock water bottle designed by Buchanan and deep water samples by a slip water bottle used by the German North Sea expedition. Bottom sediment samples were to be brought up from the sea floor using a *Hydra* sounding tube, modified in 1873 by Lieutenant C. W. Baillie. Only Sir William Thomson's sounding device, comprising piano-wire wound around a drum, was an unknown quantity. This had proved successful in trials aboard the *Lalla Rookh* in comparatively shallow water, but when it was tried aboard *Challenger* its drum collapsed; hence, depth measurements aboard *Challenger* came to be taken with hempen lines and are inaccurate. Many of the instruments used aboard *Challenger* are figured by McConnell (1981).

Challenger finally set sail from Portsmouth on 21 December 1872. Her three-and-a-half year long voyage covered some 68890 nautical miles and involved sampling at 362 stations, besides coaling stops or more protracted periods ashore at a great many ports-of-call (at many of which her crew attended or organised lavish social functions). She returned to Spithead on 24 May 1876, and was broken up at Chatham in 1921. Only her figurehead survives to this day, outside the Institute of Oceanographic Sciences in Wormley, Surrey.

Aims of the Expedition

Challenger was confidently expected to bring back the answers to all the questions posed by earlier studies of the North-East Atlantic. These were concerned largely with the nature and distribution of bottom sediments, with problems of oceanic circulation and with the very existence of life itself in the deepest parts of the oceans.

Deep-Sea Sediments

With regard to the nature of bottom sediments, important new discoveries were made almost from the outset of the voyage. The first samples recovered from the sea bed proved, as expected, to be of pale grey '*Globigerina* ooze'. It had been predicted that this would cover the entire sea floor. However, as the cruise progressed westward on the leg from Teneriffe to the West Indies and into ever deeper waters, the nature of the recovered sediments was observed gradually to change. They became darker and darker in colour, and upon microscopical examination proved to comprise fewer and fewer foraminiferal remains.

On 18 February 1873, deep-water samples from Station 3 (24 deg. 45′N; 20 deg., 14′W) were observed to contain 'a number of very peculiar black oval bodies about an inch long'. These were first thought to be fossils or lumps of pitch, but Buchanan's chemical analyses showed them to be composed of almost pure manganese peroxide. They were the first recorded examples of what we now term manganese nodules.

On 26 February 1873, a sample brought up from 3150fm. proved to comprise, in Wyville Thomson's words 'a perfectly smooth red clay, containing scarcely a trace of organic matter'. Wyville Thomson's initial surmise was that this would turn out to be a local phenomenon. This seemed to be borne out when, from the shallower Dolphin Rise, more '*Globigerina* ooze' was recovered. However, the passage into the deeper waters of the Western Atlantic again saw clay return as the dominant substrate.

The widespread distribution of clay on the sea floor was confirmed on the leg between the West Indies by way of the Puerto Rico Trench to Bermuda. This necessitated a reconsideration by Wyville Thomson of its significance. He came to regard it as typical of deep areas, supposing these areas to be too deep to sustain the '*Globigerinae*' that made up shallower sediments. As Murray had by this time shown that '*Globigerinae*' were planktonic organisms ubiquitous in surface waters and raining down upon the whole sea floor upon death, a problem arose. What could account for their absence in deep areas? Close inspection of samples from progressively deeper waters showed a progressive disappearance not only of foraminifera but also of all other calcareous organisms. Wyville Thomson came to the conclusion that a chemical reaction was removing calcium carbonate at depth and that the product of this reaction was clay. Buchanan invoked carbonic acid as responsible for the carbonate dissolution, and modelled the reaction in his laboratory. The 'snow line' below which calcite passes into solution was first described by Murray and the Belgian Abbé Renard. It was with this that the modern idea of the calcite compensation depth was conceived, though it was not until the latter half of this century that it was named as such and fully quantified.

In 1875 *Challenger* set out into the Pacific for the first time, following the American U.S.S. *Tuscarora* and the German S.S. *Gazelle*. The combined efforts of all three vessels showed this ocean to differ markedly from all others, not only in terms of its greater areal extent but also in terms of its greater depth. By virtue of the latter feature, it was found also to comprise proportionately larger areas underlain by clay. Here, though, the clay was associated with larger mineral particles. This led Murray to question Wyville Thomson's theory that the clay represented the residue derived from dissolution of '*Globigerina* ooze'. Murray came to favour a volcanic origin for the clay, citing as evidence the proximity of numerous volcanic centres (the 'Pacific ring of fire') and the relative ease with which their products could be transported into deep water. Militating somewhat against this was the associated occurrence of manganese nodules of apparently concretionary habit. Murray ascribed the origin of these nodules to volcanism also, while Buchanan had by this time come to favour mineralisation of organic remains as the most likely mechanism for their formation. Later, the French geologist Dieulafait hypothesised that they originated by precipitation from sea water at the surface following

a reaction between salt water and the atmosphere. Even to this day, their precise origin remains somewhat problematic.

Oceanic Circulation

In 1873, on the leg between Bermuda and Halifax, Nova Scotia, a detour was made to enable *Challenger* to study the Gulf Stream. This had first been described by the sixteenth-century explorer Ponce de Leon, following a voyage from Puerto Rico to Teneriffe which crossed what is now termed the Florida Current in the vicinity of Cape Canaveral. Conjectures about its nature were published by Peter Marytr of Anghrera also in the sixteenth century, and the line of demarcation between warm and cold water masses was first recorded by Lescarbot in the seventeenth. Cold water eddies were known by 1810, and there had been a great deal of subsequent research done by the U.S. Coast Survey: a synthesis of data had been published in 1868.

Serial temperature measurements made by the *Challenger* crew essentially confirmed what had been observed earlier, namely that there was a relatively shallow body of warm water forming the current and a deeper body of cool water underlying it and rising to the surface at its western flank.

Velocity measurements were made both at the surface and at depth on the whole of the ensuing equatorial Atlantic leg in order to ascertain whether there was any subsurface movement of water in a direction counter to that at the surface. A drogue of similar design to that used by Nares and his crew aboard the *Shearwater* was used to track the undercurrents. At Station 106, it was shown using this apparatus that the stength of the surface current diminished with increasing depth and ceased to have any measurable effect at 75fm. Unfortunately, the shipboard scientists were content to note at this juncture 'how very superficial the Equatorial Current is'. Had they made additional measurements at greater depth, they would undoubtedly have discovered for the first time the existence of the Equatorial Counter Current. As it transpired, this was discovered by Buchanan during a subsequent cruise on the cable vessel *Buccaneer*.

As *Challenger* sailed from the Cape Verde Islands to Brazil, the temperature readings that she was taking were observed to form a distinct pattern. Nares speculated that the 'cold stream' to the west was separated from warmer waters to the east by a north-south trending shoal system (subsequently confirmed by sounding) that acted as a barrier to mixing. We now recognise this as the Mid-Atlantic Ridge, a centre of sea-floor spreading, and the Walvis Ridge (discovered when *Challenger* re-entered the South Atlantic in 1876) running roughly at right angles to it as a transform fault system. The numerous 'sills' recorded in the East Indian archipelago are also now interpreted in terms of modern plate tectonic theory, as parts of an island arc system.

While the *Challenger* crew and scientists relaxed at one of their many ports-of-call (Sydney, Australia) in March 1874, controversy was raging back in England over the causes of ocean currents. It had been contended by Carpenter that the motive force lay in the superior weight of one column of water over another. This thesis was held to be untenable by James Croll, in that it presupposed the existence of a significant difference in level between one part of the ocean and another. Observations from the *Challenger* cruise did seem to indicate that a dynamic circulatory system could be generated and maintained by temperature gradients, as then advocated by Carpenter. But Croll remained unconvinced, citing wind-stress as an equally likely alternative explanatory mechanism. He attacked Carpenter from many fronts, having at his disposal a greater knowledge of physical processes and a commendable tenacity. But he was unable to win the war of words, in which Carpenter's literary grace was a great advantage, or indeed to shift Carpenter from his entrenched position. Later, Wyville Thomson was to argue that

there was not the slightest ground for supposing that such a thing existed as 'a general vertical circulation of the water of the oceans depending upon differences of specific gravity'.

The debate ended somewhat acrimoniously and far from satisfactorily. The modern view (e.g. Sverdrup, Fleming & Johnson, 1942) is that no one simple model in isolation can explain the dynamics of ocean circulation. Rather, it is seen as due to the dynamic interaction of a large number of variable forces and as resulting in a complex series of inter-related movements. We can thus perhaps excuse Carpenter and Croll their simplistic models, which at least accounted for some of the phenomena observed by their time.

Life in the Deep Sea

As recently as the 1840's, Edward Forbes, a lecturer in natural sciences, had stated quite categorically following the voyages of the *Beacon* in 1841 and 1842 that conditions below 300fm. were incapable of sustaining life. He saw this as due to the lack of light penetration at those depths, which meant that there could be no photosynthesis. This in turn meant that there could be no plant life and consequently therefore neither the oxygen nor the primary food source necessary for the sustenance of animal life.

Wyville Thomson, though, had cause to doubt Forbes's 'Azoic Theory'. He was aware of the findings of lowly life-forms at great depths during the voyage of the *Bulldog* in 1860 (Wallich, 1862) and had first-hand reports of the forms attached to the Bona submarine cable off Sardinia at a depth of 1000fm. from his Edinburgh colleague Fleeming Jenkin. He had therefore set sail in 1868 aboard the *Lightning* and in 1869 aboard the *Porcupine* to investigate for himself the possibility of life in the deep-sea, finding abundant evidence of it to depths of 600fm. off the Shetlands and Faeroes on the former cruise and to 2000fm. off Ushant on the latter. It was with the publication of the results of the voyages of the *Lightning* and *Porcupine* (Wyville Thomson, 1873) that Forbes's 'Azoic Theory' finally came to be discredited (Rice *et al.*, 1976; Mills, 1978, 1984; Rehbock, 1979; Rice, 1986).

Nonetheless, it still came as something of a revelation when *Challenger* discovered worm tubes from a depth of about 3000fm. in March 1873. These were identified by Willemöes-Suhm as Annelida. This, and subsequent similar discoveries, prompted Wyville Thomson to note that 'conditions of the bottom are not only such as to admit the existence of life, but are such as to allow of the unlimited extension of the distribution of animals high in the zoological series, and closely in relation to the faunae of shallower zones'. It was inevitable in the light of this finding that there would come to be developed a theory of abyssal circulation and regeneration of bottom waters.

Meanwhile, important observations were also being made on the surface-dwelling and intermediate faunae recovered by plankton tows. Murray was able to document for the first time the diurnal vertical migration of many species. He was also able to confirm that the planktonic foraminifera in surface waters (see Plate 3, p. 120) were of the same species as those comprising the bulk of the underlying sediments. Up until this time, it was only surmised and sometimes openly contested that the '*Globigerina* ooze' consisted essentially of planktonic rather than benthonic species.

Also of note was the finding that the abundance and diversity of planktonic foraminifera varied greatly with latitude. The diversity tended to be much lower in higher latitudes, and in the highest latitudes few if any specimens were found: here, the '*Globigerina* ooze' passed into diatom ooze.

Particularly noteworthy was the following observation, probably the first on any living planktonic foraminifer, by Wyville Thomson (1877):

> On one occasion in the Pacific, when Mr. Murray was out in a boat in a dead calm collecting surface creatures, he took gently up in a spoon a litle globular gelatinous mass with a red centre and transferred it to a tube. The globule gave us our first and last chance of seeing what a pelagic foraminifer really is when in its full beauty. When placed under the microscope it proved to be a *Hastigerina* in a condition wholly different from anything we had yet seen. The spines, which were mostly unbroken, owing to its mode of capture, were enormously long, about fifteen times the diameter of the shell in length; the sarcode, loaded with yellow oil-cells, was almost all outside the shell, and beyond the fringe of yellow sarcode the space between the spines to a distance of about twice the diameter of the shell all round was completely filled up with delicate bullae . . . as if the most perfectly transparent portion of the sarcode has been blown out into a delicate froth of buttles of uniform size. Along the spines fine double threads of transparent sarcode, loaded with white granules, coursed up one side and down the other, while between the spines independent thread-like pseudopodia ran out, some of them perfectly free and others anastomosing . . . , but all showing the characteristic fluid movement of living protoplasm. The [accompanying] woodcut [based on drawings by Wild, the originals of which are now among the *Challenger* MSS. in the Special Collections Department of Edinburgh University Library], excellent though it is, gives only a most imperfect idea of the complexity and the beauty of the organism with its swimming or floating machinery in its expanded condition.

In the deeper parts of the Pacific (below about 4000fm.) in 1875 a new type of sediment was discovered. As this was a type of red clay but contained a high proportion of siliceous radiolarian sclerocoma, it came to be termed radiolarian ooze. Working on this material led incidentally to the solution of the mystery surrounding *Bathybius*. *B. haeckelii* had orginally been described by Huxley in 1868 from samples collected by the *Cyclops* and preserved in spirit. It was regarded as a form of protoplasm and at the time was central to the debate on abiogenesis or spontaneous generation of life from mud. Wyville Thomson, with Buchanan's help, demonstrated apparently conclusively that it was of mineral origin and represented an artefact of preparation technique (a precipitate in spirit of the calcium sulphate in sea water). Latterly, Rice (1983) has put forward a possible alternative hypothesis, envisaging *Bathybius* as an aggregated mass of phytoplankton bound by an amorphous matrix.

Achievements of the Expedition

From the point of view of increasing knowledge of the nature and distribution of deep-sea sediments, the voyage of the *Challenger* was hugely successful. Pioneer work by Buchanan and especially Murray opened up an almost entirely new field which Murray was to make peculiarly his own.

Despite primitive sampling methods, the biological aims of the cruise were also amply fulfilled. A tremendous amount of material was collected from trawling stations from all over the world and from dredging stations to the greatest depths ever sounded. This material had been sorted, where necessary preserved and classified into the main systematic groups for further analysis, identification and description. For this further study, Wyville Thomson carefully recruited seventy-six acknowledged international specialists, who for their services received a small honorarium to cover their expenses, a commemorative *Challenger* medal and eventually a personal copy of the report in which their results were published: many appear also to have acquired or sent to their colleagues duplicate sets of specimens!

About half of the species described (including about a quarter of the foraminifera) proved to be entirely new to science. Not only was this taxonomic synthesis invaluable in its own right, it permitted ecological analysis on an ocean—or world-wide basis for the first time. The deep-sea fauna proved to be remarkably cosmopolitan. Wyville Thomson was able to note that it bore close affinities to the shallower water fauna of high latitudes, 'no doubt because the conditions of temperature, on which the distribution of animals mainly depends, are nearly similar [in the two types of environment]'. Also that its relations with Tertiary and newer Mesozoic faunae were much closer than those of the faunae of shallow water, though not as close as he had been led to expect.

Only in the area of physical oceanography did the voyage fail to achieve wholly satisfactory results, though even here it fuelled debate and encouraged further study. Of all the criticisms that have been levelled at it, the most telling was that it did not incorporate a physicist. As it was, it was left to the chemist Buchanan to make whatever measurements he could of density, salinity and dissolved oxygen. Instruments such as the current drogue and reversing thermometers were certainly not used to their full potential. It was Buchanan, too, who was able to demonstrate by obtaining from his piezometers indirect but independent temperature values that the Miller-Casella readings were inaccurate. In view of this finding, and of the crucial importance of temperature in the debate on oceanic circulation, all earlier data had to be reassessed. It was therefore not until 1877, when Wild's book *Thalassa* was published, that the physical results of the *Challenger* cruise were adequately synthesised.

Contemporary opinions on the value of the *Challenger* expedition were divided. One rather bitter contemporary British commentator wrote, in an article reproduced in the journal *Hydrospace* in December, 1971:

> The first volume recording the adventures of the *Challenger* yachting trip is now out, and the other fifty-nine will be ready in less than a century. Everyone knows that Mr. Lowe sent a man-of-war laden with Professors, and that these learned individuals amused themselves for four years. They played with thermometers, they fished to all depths from two feet to three miles, they brought up bucketfuls of stuff from the deep-sea bottom, and they plottered about and imagined they were furthering the Grand Cause of Science. Then the tons of rubbish were brought home, and the genius who bossed the expedition proceeded to employ a swarm of foreigners to write monographs on the specimens. There were plenty of good scientific men in England, but the true philosopher is nothing if not cosmopolitan; so the taxpayers' money was employed in feeding a mob of Germans and other aliens. The whole business has cost two hundred thousand pounds; and in return for this sum we have got one lumbering volume of statistics, and a complete set of squabbles which are going on briskly wherever two or three philosophers are gathered together. I believe the expedition discovered one new species of shrimp, but I am not quite sure.

In contrast, a letter (now among the *Challenger* MSS. in the Special Collections Department of Edinburgh University Library) signed by the Austrian scientist Suess and several of his colleagues, dated 12 June 1876 and addressed to 'The Editors of the Periodical *Nature*, London', reads:

> Gentlemen, After having followed the reports of the Naturalists of H.M. Ship Challenger with the utmost interest we beg leave to ask you kindly to transmit this simple but sincere expression of a hearty welcome and of thankful admiration to those distinguished gentlemen, as well as to the officers and

crew of this gallant ship which has been called to render so prominent services to science.

The consensus of current opinion (as apparent from retrospective reviews written in commemoration of the *Challenger* centenary (Deacon (1971, 1972), Linklater (1972), Yonge (1972) & Charnock (1973)) is that the *Challenger* expedition was one of the most significant in the history of science.

'Reports of the Scientific Results of the Voyage of H.M.S. Challenger'.

The publication of the *Reports of the Scientific Results of the Voyage of H.M.S. Challenger* was the joint responsibility of the series editor and the Treasury. Wyville Thomson was the editor until his resignation on the grounds of ill health at the end of 1881, whereupon Murray was appointed as successor. Treasury parsimony then led to Murray drawing on his own personal fortune to finance the publication of the fifty lavishly-illustrated royal quarto *Challenger* volumes to appear between 1880 and 1895. these included a *Narrative of the Cruise: a General Account of the Scientific Results of the Expedition* by Murray, Buchanan, Moseley and Staff-Commander Tizard, published in two parts in 1885, and six other volumes to which Murray contributed personally.

Incidentally, the cost of the whole enterprise (estimated at one hundred and seventy thousand pounds sterling) was more than offset by the profits brought about by the exploitation of the phosphate deposits of Christmas Island in the Indian Ocean. These had been discovered quite by chance in 1886 by the *Flying Fish*, on a cruise which had been organised by Murray for the purpose of increasing knowledge of coral reefs. When Murray heard about the discovery from the Commanding Officer of the *Flying Fish* who had served with him on the *Challenger*, he was quick to turn unexpected good fortune to greater advantage. He promptly hired the geologist H. P. Guppy to conduct a detailed survey, and, when he found out that the phosphate deposits were of commercial importance, urged annexation of the island and its valuable resources to Great Britain. On 4 April 1888, he wrote a letter (which survives to this day in the Palaeontology Library of the British Museum (Natural History) and makes interesting reading) to Sir Henry Thurston Holland, Secretary of State for the Colonies, on this subject, and in June of that year, the *Imperieuse* landed on Christmas Island and hoisted the Union Flag there.

Murray, ever astute in matters of business, then helped to found the Christmas Island Phosphate Company, which, as the Admiralty Hydrographer later wrote 'provided ... more than the whole cost of the Challenger expedition'. After the death of co-founder Irvine, some of the company's profits were used to set up the Irvine Chair of Bacteriology at Edinburgh University which is still in place to this day.

This illuminating episode in Murray's life is chronicled in an article that appeared in the *Scotsman* of 8th March 1914 entitled 'Christmas Island: Fortune from a No-Man's Land'.

HENRY BOWMAN BRADY (1835–1891)

Henry Bowman Brady (see Plate 4) was born on 22 February 1835 in Gateshead in the North-East of England, where his parents had settled in 1829. His father, also called Henry (1805–1883) was a respected medical practitioner and surgeon: he was also, as his

Plate 4 **Top left:** Brady as a young man, probably c. 1868–1870. **Top right:** Brady as an older man. This is the best-known photograph of Brady, and is the one used by Adams (1978) in his recent biography. **Bottom left:** Jones. **Bottom right:** Parker. From the Brady Family Photograph Album. Reproduced by kind permission of Newcastle-upon-Tyne City Libraries & Arts.

biographers (his son-in-law and daughter) T. C. and H. B. Watson in Steel (1899) put it, 'emphatically a Christian physician' who had 'yielded to a call to the ministry' in 1861 and was a member of the Religious Society of Friends (Quakers), offering prayer with 'marked reverence and fervency' and inculcating in his children moral values which remained with them throughout their lives. His mother, Hannah (1802–1872), daughter of Ebenezer and Ann Bowman of One Ash Grange, Derbyshire (where the Brady family spent its summer holidays) was an 'active worker in many of the charitable agencies of Gateshead'. His elder brother, George Stewardson (1832–1921) went on to occupy the Chair of Natural History at the University of Durham and to achieve international recognition for his work on the Ostracoda (see, for instance, Davis & Horne, 1985). He had seven other brothers and sisters, including Thomas, who was born in 1837 and whose descendants survive to this day (he never himself married).

The young H. B. Brady no doubt had an interest in natural history fostered by his father (a keen amateur naturalist), by Tuffen West (an apprentice of his father's who was involved in dredging expeditions supported by the British Association in the 1860's and later achieved fame as an illustrator of zoological monographs), by the teachers in the two Quaker schools at which he was educated (Ackworth and Tulketh Hall near Preston), and by John Storey (a teacher, botanist and Secretary to the Tyneside Naturalists' Field Club from 1849–1857) and various other members of the colony of naturalists which had its headquarters in the North-East of England for many generations (Albany and John Hancock, Bewick and Alder among them).

It was evidently a lifelong interest: one of Brady's many letters to Dr. A. Gunther, Keeper of Zoology in the British Museum (Natural History), (now in the archives of the General Library of that institution), dated 19 November 1878, concerned Ant-Eaters. Another letter to Gunther, headed Devonshire Club, St James's SW and dated 6 May 1887, reads:

> You were so kind as to tell me some time ago that if I desired tickets for the Zoological Gardens I need not hesitate to ask you. Can you provide me with three tickets for Sunday week, May 15th—I have a niece in town who would be much pleased by the attention.

Brady left school in 1850 at the age of fifteen to serve as an apprentice to a Mr. T. Harvey or R. Richards (sources differ), a chemist in Leeds, for four years. He then went on to study pharmacy in the laboratories of Dr. T. Richardson, the forerunner of the Newcastle College of Medicine. On graduating in 1855, he set himself up as a wholesale and retail pharmacist on the corner of St. Nicholas' Square in Newcastle. His commercial career prospered from the start, possibly because pure drugs had previously been in short supply. He was soon able to move to larger premises in Mosley Street and to diversify into the export trade and into the sale of scientific instruments. In the latter function, he established important contacts with many eminent scientists. His ready acceptance by the inner sanctum of late nineteenth-century foraminiferologists may have been attributable in some measure to his business reputation.

Brady's dynamic energy and organisational ability were both evident in his role as pharmacist. He was largely responsible for the foundation of the British Pharmaceutical Conference and was an active member thereof, serving both as Treasurer (1864–70) and later President (1872–73). He also served on the Council of the Pharmaceutical Society and was a member of the Board of Examiners until 1870 (when ill-health forced him to retire). Further, he did much to promote the scientific education of pharmaceutical chemists and was instrumental in transforming the *Pharmaceutical Journal* (to which he was a regular contributor) from a monthly to a weekly publication. Accolades from professional colleagues were many. Brady was elected an Honorary Member of the

American Pharmaceutical Association, the Philadelphia College of Pharmacy and the Pharmaceutical Societies of St. Petersburg and Vienna.

His hunger for intellectual activity also manifested itself in fields other than those directly associated with his work, even early on. He became an enthusiastic member of the Tyneside Naturalists Field Club (incidentally the second oldest in the country) and the Northumberland, Durham and Newcastle-upon-Tyne Natural History Society. His first papers on the foraminifera appeared in the 1860's in the transactions of these societies and as a report of the British Association for the Advancement of Science (Brady, 1863, 1864a–b, 1865a–b) and essentially concerned those living off the coasts of his native North-East (see also Woodward, 1972). Another significant milestone in Brady's early career was the co-publication with Carpenter (Carpenter & Brady, 1869) of a monograph of the genera *Loftusia* and *Parkeria* (the latter now known to be non-foraminiferal). This work received extremely favourable reviews from Duncan and Parker, the originals of which are now to be found among the Referees Reports in the Archives of the Royal Society. It is testimony to Brady's dedication that over thirty subsequent publications on the group (ranging in age from Silurian to Recent) were forthcoming during the course of his working life, notwithstanding the many and varied demands on his time. In recognition of his signal services to natural science he was elected a Fellow of the Geological Society in 1864 and a Fellow of the Royal Society in 1874. In a letter headed Mosley St., Newcastle-on-Tyne and dated 6 June 1874, Brady wrote to Stokes at the Royal Society acknowledging the latter honour and adding 'I hope to be attending for admission on the 18th Sept.'. This letter now resides among the Miscellaneous Correspondence in the Archives of the Royal Society.

Brady was so successful in business that he was able to sign over his business to his one-time assistant and later partner Nicholas Martin in 1876 (at the age of 41) and to devote the remainder of his fruitful life to the full-time study of the foraminifera. In his work on the group, he was variously associated with most of the leading contemporary authorities, including his sometime co-authors Carpenter (see Plate 1), William Kitchen Parker and Thomas Rupert Jones (see Plate 4; see also Murray, 1981, 1989). Together with Fortescue William Millett and William Crawford Williamson, these luminaries constituted what was to become known as the 'English School'. The broad species concept of the taxonomically conservative 'English School' contrasted radically with the philosophy of the 'Continental School' (personified by Auguste Emanuel Reuss, Christian Gottfried Ehrenberg (see Plate 5), Alcide Dessalines d'Orbigny and others).

The pinnacle of Brady's achievements as a foraminiferal worker was undoubtedly achieved with the publication of the *Report on the Foraminifera dredged by H.M.S. Challenger During the Years 1873–1876* (hereafter *Challenger Report*). Brady's work on this colossal project began in 1878 and ended with the submission to the publishers of the final instalment in 1884. The 814 pages of text (written in a delightfully idiosyncratic style far removed from the modern terseness) set new standards of comprehensive presentation of information and attention to detail and make the *Challenger Report* an indispensable reference even to this day. The bibliographic section alone occupies 46 pages! Brady's accuracy of observation was particularly examplary and is perhaps his most enduring legacy. He personally supervised the production of the 116 magnificent colour plates by the skilled draughtsman and lithographer A. T. Hollick, which are of a standard rarely matched before or since. Records in a plate proof receipt and despatch book owned by James Chumley of the *Challenger* Office, 45 Frederick Street, Edinburgh (now in the Special Collections Department of Edinburgh University Library) indicate that this in itself was a very time-consuming task, beginning in 1882.

In later life, Brady received many prestigious awards and honours for his contributions to foraminiferal studies, among them a gold medal from the Austrian Emperor Franz Joseph I (see below) and an honorary doctorate from the University of Aberdeen. The

Plate 5 **Left:** Ehrenberg. **Centre:** Reuss. **Right:** Karrer. From the Brady Family Photograph Album. Reproduced by kind permission of Newcastle-upon-Tyne City Libraries & Arts.

letter advising him of the latter honour is among some of the uncatalogued Brady papers in the Library of the Royal Society. It is dated 3 March 1888 and signed H. Alleyne Nicholson and reads 'My Dear Brady, I write a most hurried note in order to catch the early Sunday mail tomorrow morning for the south, that I may have the great pleasure of telling you that the University of Aberdeen has to-day, on my proposal, conferred upon you the degree of LL.D.'. He was also appointed as Corresponding Member of the Imperial Geological Institute of Vienna, made an Honorary Member of the Royal Bohemian Museum, Prague and sat on the 'Committee of Papers' of the Royal Society. His review of 3 June 1889 of a paper by Bateson 'on some varieties of *Cardium edule*' resides among the Referees Reports in the Archives of the Royal Society.

Like many other products of his generation, Brady had a great zest for life. Despite (or perhaps because of) his delicate health (he was troubled by pulmonary disease for many years), he was an avid gentleman-traveller. He journeyed twice around the world, visiting such places as Morocco, India, Ceylon, China, Japan, Java, the Pacific Islands, Australia, New Zealand and the United States. He seems to have been particularly fascinated by the Orient, and filled the house he had bought for his father's retirement ('Hillfield' at the top of Windmill Hill in Gateshead) with Japanese paintings, vases and curios.

His interest in the local flora and fauna he encountered and the native customs he observed on his travels frequently prompted him to write short pieces. One of his letters to Gunther, headed Hillfield and dated 28 October 1878, reads:

> During a recent visit to the interior of Morocco, I made a good many observations in respect to the snake performances as practiced by the Clissowa.

A subsequent letter, dated 13 November 1878, thanks Gunther for his '. . . obliging letter just to hand . . .', and laments the lack of '. . . accurate knowledge on the characters of snakes . . .' displayed earlier, adding: '. . . had they only been Protozoa, I could have told you more about them—but this comes from having lapsed into a specialist'.

On his last overseas trip, to the Upper Nile in 1889–1890, Brady fell seriously ill with oedema of the feet and legs. He spent some time laid up in Cairo before being forced home. On his return, he took up residence in Bournemouth, where he lived as a semi-invalid and was unable to fulfil his final ambition (alluded to in a letter to Gunther dated 22 May 1888) of producing a monograph of the British Foraminifera.

Brady died of pneumonia on Saturday 10 January 1891. The *Newcastle Daily Chronicle* posted a short obituary notice the following Monday, and an account of the funeral the following Thursday. Obituaries were also published in the *Geological Magazine*, in the *Pharaceutical Journal* and in the 'Notices of Fellows Deceased' in the *Proceedings of the Royal Society* for 1891–1892 (the last-named by the metallurgist W. C. Roberts-Austen).

Brady's most fitting epitaph is provided by Dr. Michael Foster, who wrote in the issue of *Nature* dated 29 January 1891:

> Science has lost a steady and fruitful worker, and many men of science have lost a friend and helpmate whose place they feel no-one else can fill. His wide knowledge of many branches of scientific inquiry and his large acquaintance with scientific men made the hours spent with him always profitable; his sympathy with art and literature, and that special knowledge of men and things which belongs only to the travelled man made him welcome also where science was unknown; while the brave patience with which he bore the many troubles of enfeebled health, his unselfish thoughtfulness for interests other than his own, and a sense of humour which, when needed, led him to desert his usual staid demeanour for the merriment of the moment, endeared him to all his friends.

Readers interested in further details of Brady's life are referred to the two fine and factual biographies known to the author, the one contemporary (by his brother-in-law Thomas Carrick Watson, in Steel, 1899), the other modern (Adams, 1978).

Brady Library

Watson, the executor of Brady's will, wrote to the Treasurer of the Royal Society in a letter (now among the Miscellaneous Correspondence in the Archives of the Royal Society) headed 83 Osborne Road, Newcastle-upon-Tyne and dated 2 July 1891: 'I beg to hand you herewith ... eight hundred pounds, being the sum bequeathed by the late Henry Bowman Brady to the Royal Society.'

Five hundred pounds was to be placed in the Scientific Relief Fund of the Royal Society in accordance with Clause 10 of the will. The remaining three hundred pounds was to be used for the maintenance and increase of the Brady Library in accordance with Clause 3 of the will, which read:

> I bequeath all my books and papers relating to the Protozoa to the Royal Society and I recommend for the greater convenience of reference thereto the said books and papers should be kept together in one place and a distinct collection ....

The Brady Library, incidentally the only named collection in the entire Library of the Royal Society (though currently in the basement!) now comprises some 180 volumes. Among these are a number of rare and valuable books by such authors as Agassiz, d'Archaiac & Haime, Batsch, de Blainville, Costa, Dujardin, Ehrenberg, Fichtel &

Moll, Geinitz, Haeckel, Karrer, Karrer, d'Orbigny, Schaudinn, Seguenza, Silvestri, Soldani, Spengler, Stache & Schwager and Terquem. Also in the collection are a complete early run of the journal *Annals and Magazine of Natural History* and volumes of reprints and unpublished manuscripts and drawings by various workers annotated by Brady himself, some of which are bound under the title *Memoirs and Papers Relating to the Foraminifera*. Some material has been bound and some added by the Royal Society.

Some letters, manuscripts and sundry papers are archived separately in the Library of the Royal Society.

The letters include one from Edward Heron-Allen to the Library Committee of the Royal Society, headed 33 Hamilton Terrace N.W. and dated 21 October 1914, which reads:

> Gentlemen, By the introduction of Prof. Herdman and with the kind and courteous assistance of the Asst. Librarian Mr. Hastings White, it has been my privilege for some time past to make use of the unique and remarkable collection of works on the Foraminifera bequeathed to your library by the late Dr. H. B. Brady . . .

Other letters in the collection include ones to Brady from G. S. Brady, Carter [?], Guppy, Halkyard, Hantken, Howchin, Millett, Murray, Schwager and Sherborn.

The manuscripts include one 'On the shallow water and littoral foraminifera of some of the islands of the southern Pacific', probably written c. 1890 and never published.

The sundry papers include numerous drawings and tracings of foraminifera by Brady together with a key, plates of Crag foraminifera by Brady and West, taxonomic notes on Pacific foraminifera (New Caledonia, 1884, Fiji, 1884–1885 and Samoa), and distribution data on the *Challenger* foraminifera.

The *Challenger* data are contained in three black foolscap volumes. Two of these tabulate the distributions of all of the species of foraminifera figured in the *Challenger Report* (Brady, 1884), species-by-species. The first of these deals with those figured on Plates 1–55 of the *Challenger Report* (Miliolidae-Astrorhizidae-Lituolidae-Textularidae-Chilostomellidae) and the second with those figured on Plates 56–115 (Lagenidae-Globigerinidae-Rotalidae-Nummulinidae). The tables are interspersed with notes (e.g. from Rev. A. M. Norman on *Psammatodendron*). The third volume lists the distributions of all of the foraminifera figured in the *Challenger Report*, station-by-station, and adds the date on which the station was sampled, its latitude and longitude, and depth, bottom temperature and substrate data. This volume contains an unsigned note to the effect that 'Brady gives lists from . . . stations not in his Report'.

Brady Family Photograph Album

Additional insights into the Brady's shared characters may be gained by browsing through their family photograph album in the Local Studies Department, Central Library, Newcastle-upon-Tyne. The frontispiece page features one of the best-known photgraphs of Brady (that used by Adams (1978); see also Plate 4) and dedicates the album to his 'affectionate remembrance'. Many of the photographs in this remarkable and fascinating compilation were evidently taken by Brady himself: a number of the earliest ones of the Great Fire of Gateshead are dated October 1854 and signed H. B. B., and it seems reasonable to attribute some later photomicrographs (including ones of pennate and centric diatoms and holothurians) to him also. However, some were also taken by R. B. Bowman (probably a cousin) and some evidently bought as postcards, etc.

Among the photographs present in the album (this is by no means an exhaustive list) are ones of local scenes, beauty spots (home and abroad), still lives, staged set-pieces somewhat in the style of Henry Peach Robinson, family and friends (including the Quaker families Pumphrey and Robinson), literary figures (contemporary English and French authors and the Romantic Poets), works of art (principally in the classical, neo-classical, renaissance and Pre-Raphaelite schools and often with a religious theme) and architecture (principally ecclesiastical, but also industrial and municipal), contemporary figures, politicians and captains of industry (including such diverse figures as the performing artists Ellen Terry and Sarah Siddons, Florence Nightingale and the 'iron master' Crawshay, David Livingstone and the imperialist Rajah Brooke, abolitionist Abraham Lincoln and the Tsar of Russia, the Pope and Garibaldi) and leading contemporary scientists and naturalists. A touching chord is struck by the inclusion of the obviously much-loved prize-winning dog 'Cato', and a somewhat bizarre one by the inclusion of one 'Crockett the Lion Tamer'.

THE *CHALLENGER* FORAMINIFERA

The 600 cases of *Challenger* material, including 100,000 'mountable specimens' were originally assumed all to have been deposited in the British Museum (Natural History), in accordance with Admiralty instructions to that effect. However, some material was disposed of during the voyage, some was never returned by the specialists to whom it was sent for description and some was sent out on subsequent request to various institutions: in particular, sediment samples were very widely dispersed.

The history of dispersal of the *Challenger* material is admirably summarised by Lingwood (1981) and Kempe & Buckley (1987). The following discussion of the location of *Challenger* foraminiferal material is based partly on these accounts, and partly on those of Adams (1960), Adams *et al.* (1980) and Murray & Taplin (1984*a*). McConnell (in press) provides further information on the whereabouts of correspondence and papers pertaining to the *Challenger* expedition and its organisers and participants.

Foraminiferal Slides

According to records in the catalogue of '*Challenger* Office specimens sent out 1873–1915' housed in the Palaeontology Library of the British Museum (Natural History), *Challenger* material was sent to Brady in ten batches between 25 November 1882 and 9 September 1887, that despatched on 1 June 1887 being directed to 5, Robert Street, Adelphi, London WC1. This material is only recorded as having been returned in three instances! However, it would seem that little of importance remains unaccounted for.

Most of the specimens of foraminifera figured in the *Challenger Report* (Brady, 1884) are to be found in picked slides in handsome polished wood cabinets in the Heron-Allen Library in the Palaeontology Department of the British Museum (Natural History) (see Plate 6); a few are to be found in the Carpenter collection in the Royal Albert Memorial Museum, Exeter (Murray & Taplin, 1984*a*). The slides in the BM(NH) pertain to the cruises of the *Challenger* herself (1872–1876), the *Lightning* (1868), the *Porcupine* (1869) and the *Knight Errant* (1879) and to the Austro-Hungarian and British North Polar expeditions (1872–74 and 1875–76 respectively). Comparison with authenticated specimens of Brady's handwriting (e.g. signed letters to Gunther and to John Hancock (now in the museum that bears his name in Newcastle-upon-Tyne)) suggests that the

Victorian copper-plate inscriptions on the bottoms of many of these slides are attributable to the man himself.

Unfigured but sorted specimens and unpicked and unsorted residues are also to be found in slides in the Palaeontology Department of the BM(NH) (see Plate 6). Henry Sidebottom made some attempt to catalogue the former in his unpublished 'MS. index to the collection of type-slides used by H. B. Brady . . .', probably compiled at around the turn of the century. Adams (1960) and Adams *et al.* (1980) list the BM(NH) registered numbers of many of the specimens figured in the *Challenger Report* (Brady, 1884). They also discuss the status of the specimens of the 97 species described as new in the *Challenger Report* (Brady, 1884) and the 140 species described as new in earlier works (principally Brady, 1878, 1879*a–b*, 1881a–c, 1882) and subsequently figured (in many cases for the first time) in the *Challenger Report*. All of these are interpreted as syntypes. Some have been designated as lectotypes and paralectotypes.

Adams and Adams *et al.* (*op. cit.*) also give something of the history of the collections. It appears from their accounts that Brady presented the *Porcupine* material to the BM(NH) in 1885 and the *Knight Errant* material and 612 slides of *Challenger* material in 1888. At least the bulk of the remainder of the *Challenger* material was originally deposited in the University Museum of Zoology, Cambridge, whence, at the instigation of Sir Clive Forster-Cooper and Edward Heron-Allen, it was removed to the BM(NH) between 1939 and 1959 (see also Joysey, 1960). There are no records of any material remaining at Cambridge (R. Symonds, personal communication).

In fact, Brady appears to have presented some *Challenger* material to the BM(NH) as early as 1885. A letter from Brady to Gunther, headed Savile Club, Piccadilly and dated 8 October 1885, intimated that Brady expected to finish the following day '. . . sorting and arranging the collection of Challenger and other Foraminifera and mounting a suitable series for exhibition [in the BM(NH)]'. A second letter, dated 9 October, confirmed that he had indeed '. . . finished, as far as I can at the moment, the work I have been engaged upon . . . in connection with the collections'. A third letter, headed White Hart Hotel, Reigate and dated 13 October, noted that Brady was '. . . well pleased that the series of Foraminifera meets with your approval. I hope still, as I may have time, to do a good deal to render it more complete'.

Brady is also known to have presented 435 slides of *Challenger* and *Porcupine* material and practically all of the Austro-Hungarian North Polar expedition material to his friend Felix Karrer (see Plate 5) at the Naturhistorisches Museum, Vienna, in 1887, which resides there still. In recognition of this, Franz von Hauer, a geologist who at the time was director of the Museum, approached the Austrian Emperor Franz Joseph I and arranged for Brady to be presented with a gold medal inscribed 'k. k. österr.–ung. Ehrenzeichen für Kunst und Wissenschaft' (Insignia of the Royal and Imperial Austro-Hungarian Empire for Art and Science) and bearing His Imperial Majesty's portrait and device (F. Rögl, personal communication).

Additional *Challenger* material was presented to David Robertson, 117 slides of which are now in the Robertson Museum and Aquarium collection, Millport, and Art Gallery and Museum collection, Glasgow (F. Woodward, personal communication). The Hancock Museum, Newcastle-upon-Tyne also has '. . . a few slides . . .' (P. S. Davis, personal communication), and the Laboratorium voor Paleontologie, Katholieke Universiteit, Leuven, Belgium, has twelve (Hooyberghs & van de Sande, 1988).

Raw Material

A vast number of sediment sounding samples collected by *Challenger* are now housed in the BM(NH). These were originally stored in one collection in the *Challenger* expedition

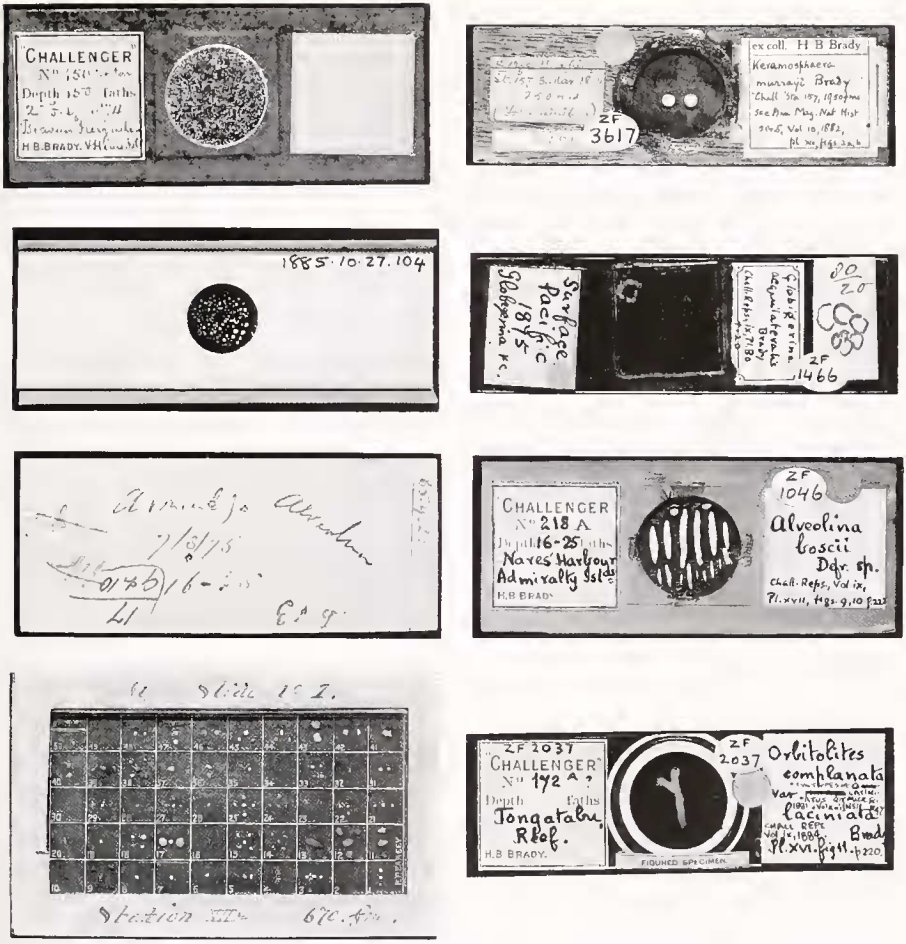


Plate 6 **Top left:** Slide of residue material from *Challenger* Station 150, between Kerguelen and Heard Island. **Upper middle left:** Slide of picked residue from *Challenger* Station 218A, Admiralty Islands (top), with old British Museum (Natural History) registered number (1885.10.27.104). **Lower middle left:** Bottom of same slide annotated by Brady. **Bottom left:** Slide of sorted residue from Station VIIC. The fauna in many of these so-called 'type slides' has been identified by Sidebottom ('MS. index to the collection of type-slides used by H B. Brady . . .'). **Top right:** Slide of the benthonic foraminifer *Keramosphaera murrayi* Brady from *Challenger* Station 157, with new BM(NH) registered number (ZF3617). **Upper middle right:** Slide of the planktonic foraminifer *Globigerina aequilateralis* Brady [now identified as *Globigerinella aequilateralis* (Brady)] from a surface tow in the Pacific, with new BN(NH) registered number (ZF1466). Figured in the *Challenger Report* (Brady, 1884; Pl. 80, Fig. 20). **Lower middle right:** Slide of the benthonic foraminifer Alveolina boscii Defrance, sp. [now *Alveolinella quoyi* (d'Orbigny)] from *Challenger* Station 218A, Admiralty Islands, with new BM(NH) registered number (ZF1046). Figured in the *Challenger Report* (Brady, 1884; Pl. 17, Figs. 9–10). Bottom of same slide annotated by Brady, with old BM(NH) registered number (1885.9.25.11). **Bottom right** Thin-section slide of the benthonic foraminifer *Orbitolites complanata* var. *laciniata* Brady [now *Marginopora vertebralis* var. *plicata* Dana] from *Challenger* Station 172A, Tongatabu Reef, with new BM(NH) registered number (ZF2037). Figured in *Challenger Report* (Brady, 1884; Pl. 16, Fig. 11).
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commission's offices in Queen Street in Edinburgh, which was moved in 1890 to nearby Frederick Street. A set of samples from this collection, one from each *Challenger* station, was sent to the Geology Department of the BM(NH) in 1895 and subsequently transferred to the Zoology Department of that institution in 1922 and to the Mineralogy Department in 1938. The remainder of the Edinburgh collection was transferred in 1904 to Sir John Murray's residence 'Villa Medusa' on the northern outskirts of the city, where it remained until long after Murray's death in an automobile accident in 1914. Here it was examined by Edward Heron-Allen and Arthur Earland in 1919 and found to comprise 9746 samples of 'Marine Deposits' (soundings, dredging, etc. in bottles and boxes), together with the *Challenger* expedition glass photographic plates, microscopical preparations and an extensive oceanographic library. This part of the collection was eventually acquired by the Zoology Department of the BM(NH) in 1921 and by the Mineralogy Department either later in 1921 (a few specimens of phosphates, etc.) or in 1935. Some of it has subsequently been transferred to the Palaeontology Department.

Murray had stipulated in 1914 to Heron-Allen that in the event of his untimely death his collection should be bequeathed either to his two sons, if they wished to carry on his work, or to a reputable institution such as the BM(NH) or to the Imperial College of Science (University of London). In the latter event a responsible curator, salaried from a trust fund, was meticulously to catalogue every sample. After the inevitable delay, this condition (subsequently stressed by the Murray family solicitor) has now been fully complied with: the Sir John Murray Collection of zoological, botanical and geological specimens from the cruise of H.M.S. *Challenger* is catalogued by Buckley *et al.* (1979, 1984) and most of it has been entered onto a computer database.

PLANNED REVISION TO THE TAXONOMY OF THE *CHALLENGER* FORAMINIFERA

The original report on the *Challenger* foraminifera (Brady, 1884) dates from what might best be termed the systematic or descriptive phase of deep-sea research. It was conceived in the pervasive intellectual atmosphere of the 'English School' and consequently embodies a broader ('lumping') species concept than is usually acceptable today (Cifelli & Richardson, 1990; Haynes, 1990). Because of its archaic taxonomy, it cannot be used without qualification in the type of analytical and synoptic work currently being undertaken.

Previous revisions to the taxonomy of the *Challenger* foraminifera include those of Nuttall (1927, 1931), Thalmann (1932, 1933, 1937, 1942) and most notably, R. Wright Barker (1960). Barker's work was particularly important and useful in that it synthesised all of the great variety of names assigned to Brady's figured species in the literature up to 1960 (including those of Nuttall and Thalmann, *opp. cit.*) However, Barker did not subjectively assess which names were valid and which not, referring simply to the '... return in ... recent times to the principles of Reuss ...', the 'splitting of a large number of Brady's "species" ...' and '... their allocation to new genera ...'. He proposed *nomina nova* for four species whose earlier names were pre-occupied, but did not formally describe the thirty-one species and three varieties he regarded as new, stating that 'a number of the forms figured by Brady, and as yet undescribed, have been indicated but have not been named, for the writer has not had the opportunity to study Brady's specimens in order to prepare adequate descriptions and to designate types.' And in many cases he left problems of generic assignment unresolved, commenting in the case of the nodosariids, for instance, that 'there is still confusion in the treatment of this group, ... and no attempt has been made to clarify the question here, the generic

names in all cases being quoted unchanged'. His work was essentially, as he himself stated, '. . . of a bibliographic nature and in no sense a critical revision of the *Challenger Report*.'

Since Barker's time there have been a large number of publications bearing on the taxonomy of the *Challenger* foraminifera: some of the more important are those of Loeblich & Tappan (1964, 1988), Shchedrina (1964, 1969), Srinivasan & Sharma (1969, 1980), Hornibrook (1971), Saidova (1975, 1981), McCulloch (1977, 1981), Zheng (1979), Haynes (1981), Rögl & Hansen (1984), Papp & Schmid (1985) and Van Morkhoven, Berggren, Edwards *et al.* (1986).

In my opinion, the taxonomic advances since Barker's time allow a fresh revision of the taxonomy of the *Challenger* foraminifera, while the growing interest in cosmopolitan deep water benthonic foraminifera and their stratigraphic, palaeobathymetric and palaeo-oceanographic potential necessitates it.

I am therefore planning a further revision of the taxonomy of the *Challenger* foraminifera. My intention is to reproduce all of the text-figures and 116 colour plates from the original report on the *Challenger* foraminifera (Brady, 1884) in book form and to annotate them with up-to-date taxonomic notes. Identifications will be based on examination of the specimens themselves in the British Museum (Natural History). Locations and depths of sampling sites from which figured specimens came will be checked at source and given in full, as will BM(NH) registered numbers and relevant information on the status of specimens (lectotypes etc.). A list of cited references and a comprehensive taxonomic index will also be given.

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Pippa Senior, Press Officer of the Royal Society and coincidentally a descendant of the Brady family provided much valuable information on the Brady family genealogy, including a family tree. This had been compiled by her great grand-mother Nora Gillie, born Brady, who was Thomas Brady's daughter and one of Henry Bowman Brady's nine nieces.

My father also assisted with some of the biographical work. My wife Heather and my colleague Mike Simmons proof-read early draughts of the text and suggested various stylistic and scientific improvements.

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